Automated Verification of Mesoscale Forecasts using
Image Processing Techniques

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LONG-TERM GOALS

The AP-UW atmospheric sciences group is working to improve forecaster performance at Navy operational weather forecast detachments afloat and ashore. This work encompasses broad research and technology development in areas of visualization, human factors, human-machine interaction, and model and forecast verification with an emphasis on mesoscale ensembles and visualization of uncertainty.

OBJECTIVES

The overall objective of this effort is to develop a highly automated, rapid, mesoscale numerical weather prediction (NWP) verification tool for use by forecasters and model developers. The verification technique should consider distortion errors (phase/timing, rotation, and stretching) as well as the normal amplitude errors. It is intended to test the verification tool on the University of Washington Short Range Ensemble Forecast System (SREF) and with a version of the Navy COAMPS model to be implemented at APL.

APPROACH

The verification technique of Van Galen (1970) and Hoffman, et al., (1995) will be implemented as a rapid, automated, web-enabled forecaster and model developer tool. This technique, originally intended for synoptic-scale features, will be tested on mesoscale predictions of a number of parameters in an attempt to separate model forecast errors into amplitude, phase, rotation, and distortion components for better evaluation of mesoscale model capabilities. In order to improve processing time, image motion processing techniques (Chan, 1993; Lim and Ho, 1998) will be implemented and tested for potential acceleration of the verification routine. The verification tool will be used to evaluate the University of Washington Short Range Mesoscale Ensemble (SREF) performance and also will be tested on an APL version of COAMPS when implemented. As an expansion of this effort, a user-focused cost-loss evaluation will be investigated for better interpretation of component verification (amplitude, phase, rotation, distortion) results.

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WORK COMPLETED

During the first year of the project, the Hoffman (1995) technique for amplitude and phase error was implemented in both MATLAB and web-enabled versions (see figures 1 and 2 below) and fully tested on idealized and real model cases. Three image motion-processing techniques were implemented in the routine and tested for both acceleration and accuracy. Three methods of error minimization (mean absolute difference (MAD), route mean square error (RMSE) and mean square error (MSE) were tested both for numerical efficiency and accuracy of localization. In addition, a competing verification technique developed by University of Minnesota was tested on idealized and real cases and a paper is currently in review.

RESULTS

The Van Galen/Hoffman technique has been successfully implemented both in MATLAB for further scientific investigation and as a prototype web-based forecaster tool in the UW Model Uncertainty Monitor (MUM). The MUM is a prototype forecaster aide being developed for testing at NPMOF Whidbey Island. An approximately 30x increase in processing speed in the verification tool has been achieved by implementing a combination of two image motion processing routines and optimizing the computer code functions. In addition, it was determined that MSE error minimization for localization produced the most reliable and accurate verification computation without significantly impacting computational speed.

IMPACT/APPLICATIONS

Verification systems need to be highly automated in order to rapidly assess large samples of cases; however, they must also be able to correctly evaluate the high frequency, high amplitude signals of mesoscale features. Unfortunately, traditional methods of verification have been shown not to work for mesoscale numerical weather prediction. Simple automated techniques incorrectly assess slight phase or displacement errors, causing smoothed, or ensemble mean forecasts to appear to perform better than a more detailed deterministic forecast, yet they contain less forecast content. Case studies, while more revealing, are too time consuming to assess the large number of cases required for subtle model biases or differences arising from small changes in model algorithms. Mesoscale NWP forecast verification is a critical issue for US Navy operations. More NWP model outputs are becoming available from various sources and it is difficult for management and operational forecasters to choose the appropriate system for each forecast situation. The forecast verification tool will enable more accurate and meaningful evaluation of mesoscale numerical weather prediction systems, especially mesoscale ensemble systems, where large volumes of data are required for accurate assessment and where small prediction distortions or displacements cause significant misinterpretation of verification results. The tool is intended for use both by model developers and by forecasters for quick and more accurate model assessment. The forecaster tool will be implemented as an easy to use web tool.

RELATED PROJECTS

The University of Washington Multidisciplinary University Research Initiative (MURI) on Integration and Visualization of Multi-Source Information for Mesoscale Meteorology: Statistical and Cognitive

Approaches to Visualizing Uncertainty. This project incorporates a number of verification techniques into a forecaster visualization tool and a prototype version of our mesoscale verification tool has been implemented here.

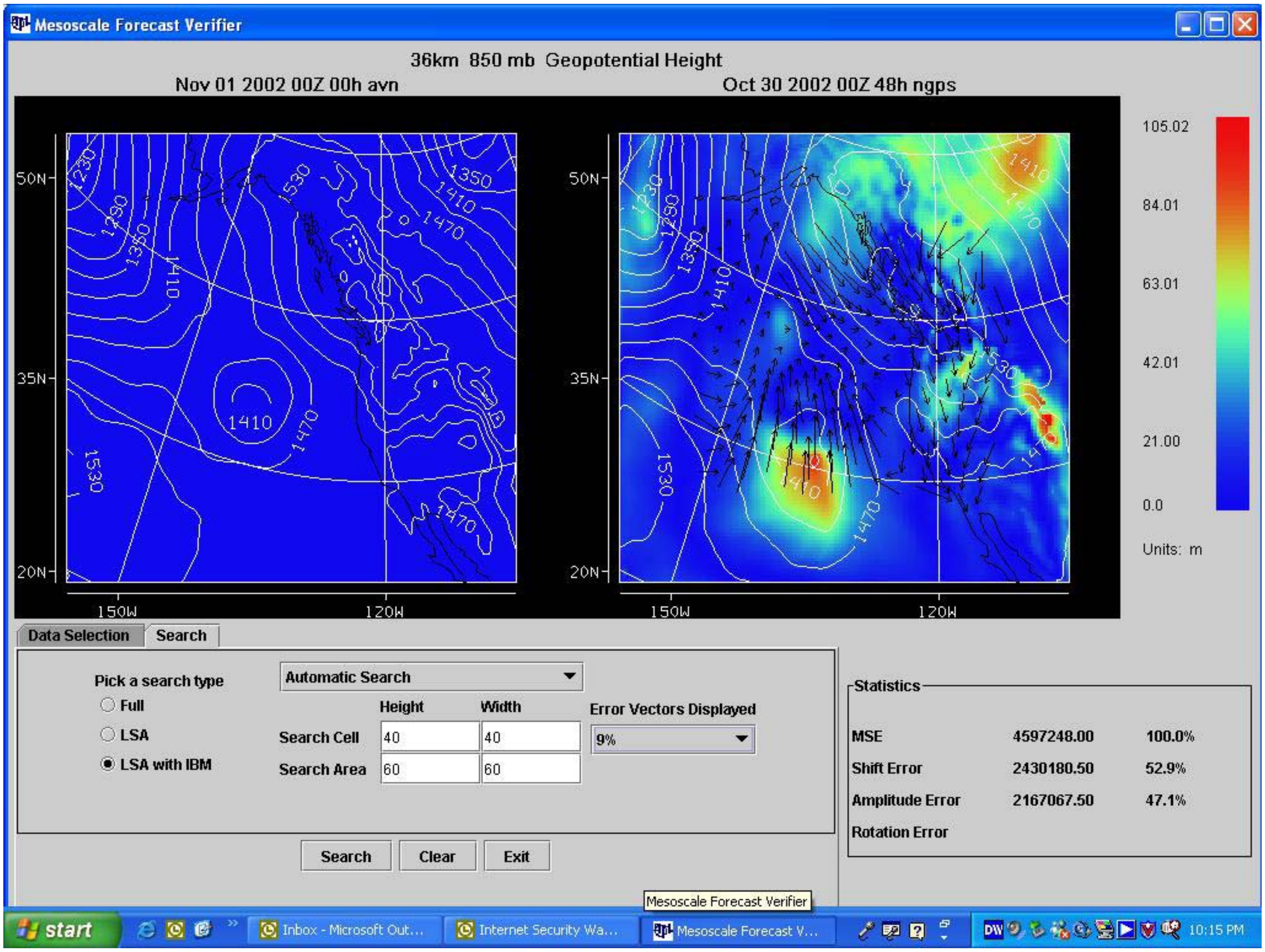

Figure 1. Mesoscale Verification Tool Full Map Verification
[Verification of the UW MM5 mesoscale forecast based on NOGAPS initial conditions for November 1st, 2002 with mean square error field and arrows indicating phase error.]

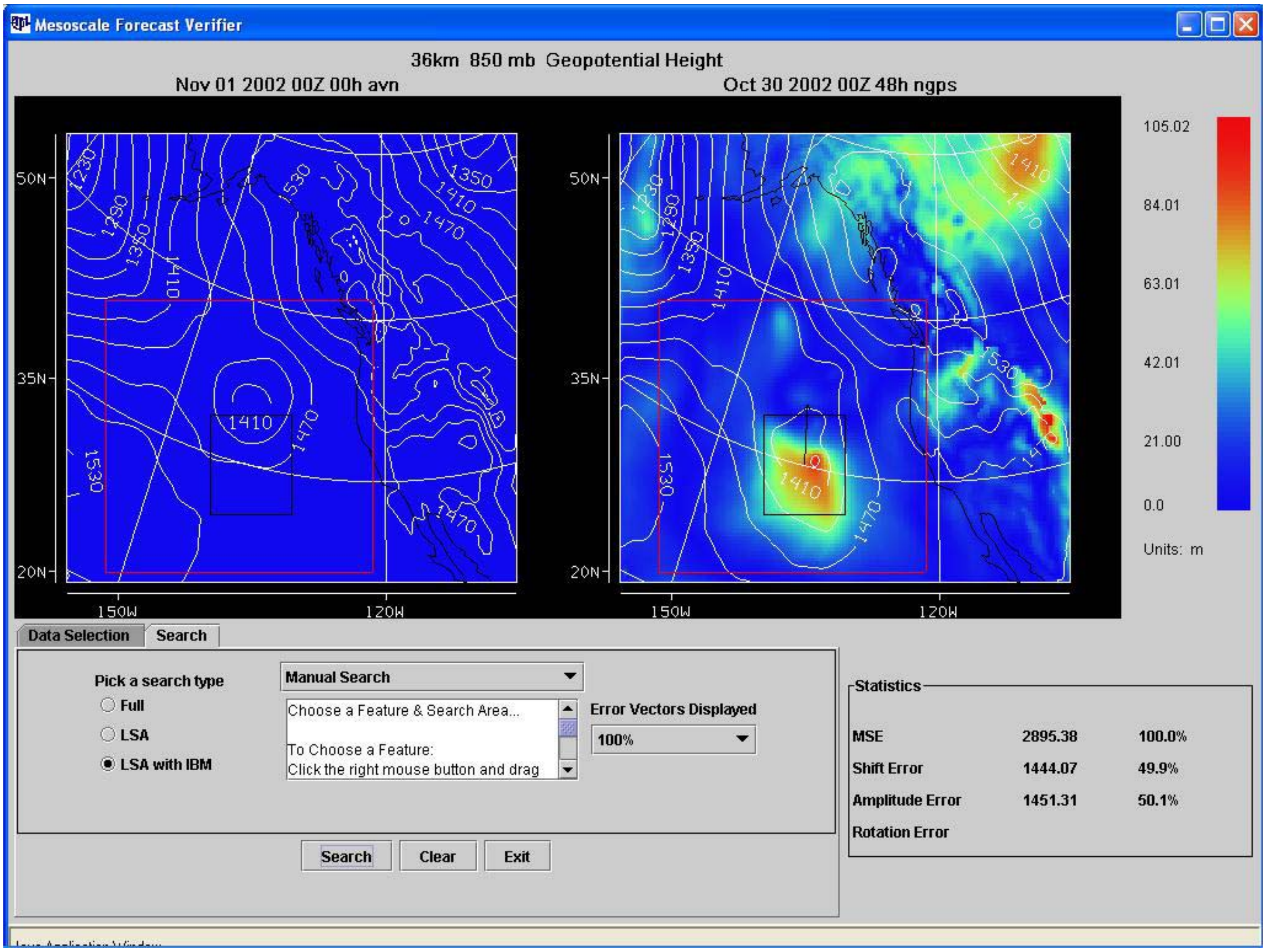

Figure 2. Mesoscale Verification Tool with User-Selected Verification Area
[Verification of a low-pressure feature demonstrating user selection of an area for verification and separation of mean square error into amplitude and phase components.]

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